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# **Applications of Rain Field Modeling in Radio Communications**

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# Introduction

The market for mobile phones is saturated, so the commercial push is for new applications to encourage users to increase usage of the operators' services

The UK spectrum auction for 3G mobile licenses in March 2000 resulted in a total of 22 billion pounds being spent by the mobile phone companies to buy the rights to certain bands of the radio spectrum

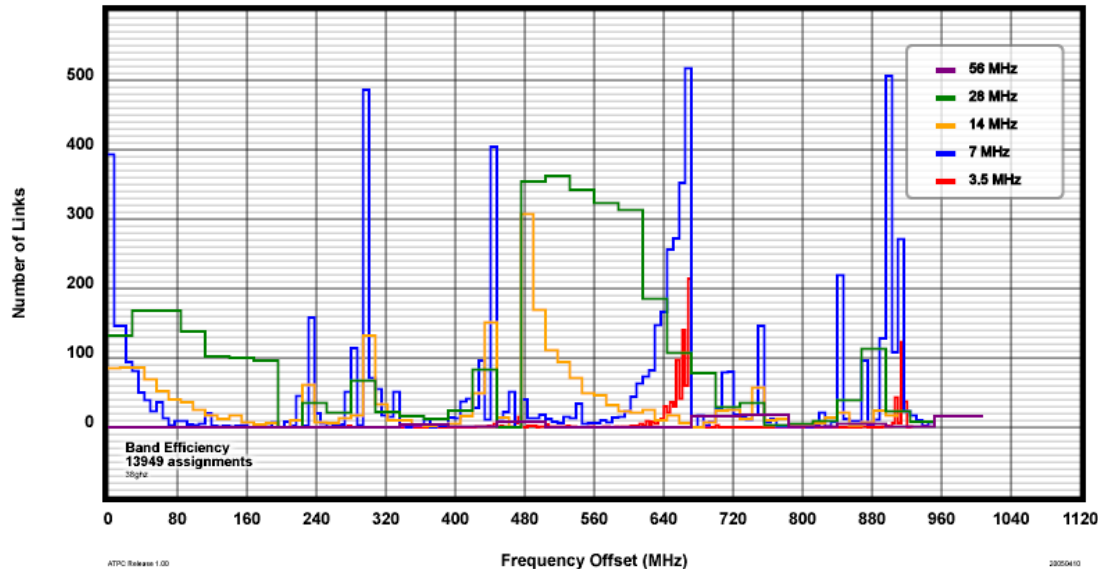
These licenses are needed in order to provide 3G services like mobile internet and TV-on-demand. These services are very bandwidth-intensive, and the radio spectrum at mobile phone frequencies is very congested, but the UK government wants to encourage growth in this technological area

So, what can we do?

1. Improve spectrum efficiency at lower frequencies
2. Open up higher frequencies (which are under-used) to commercial exploitation



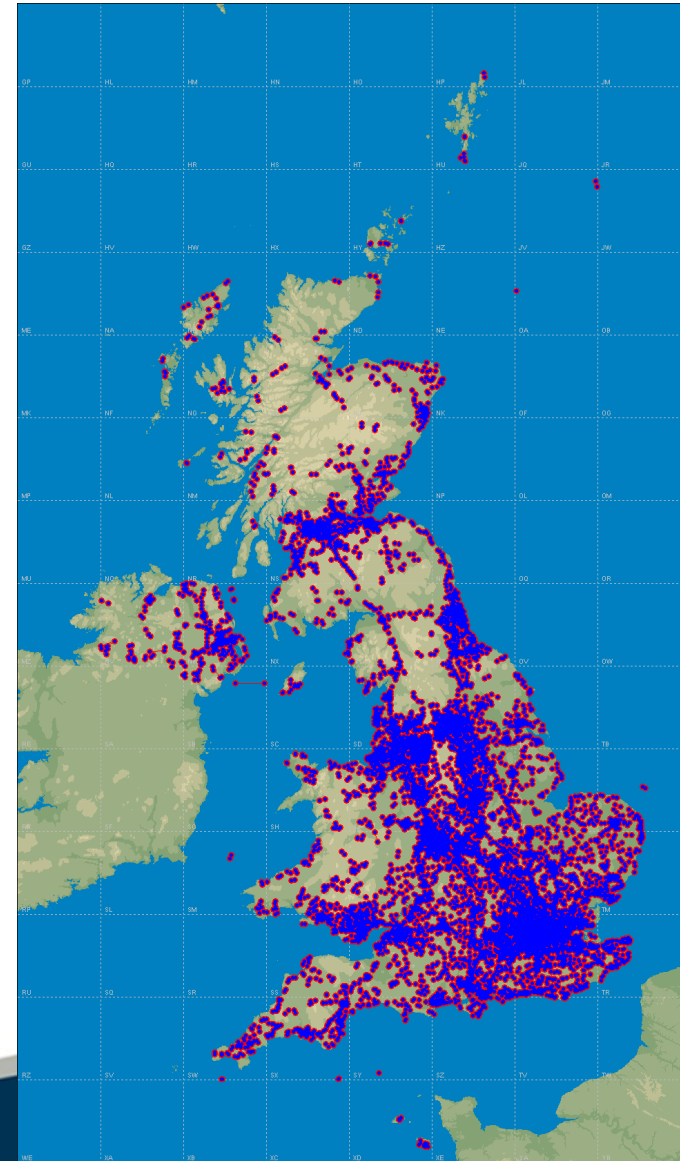
# Improving spectrum efficiency



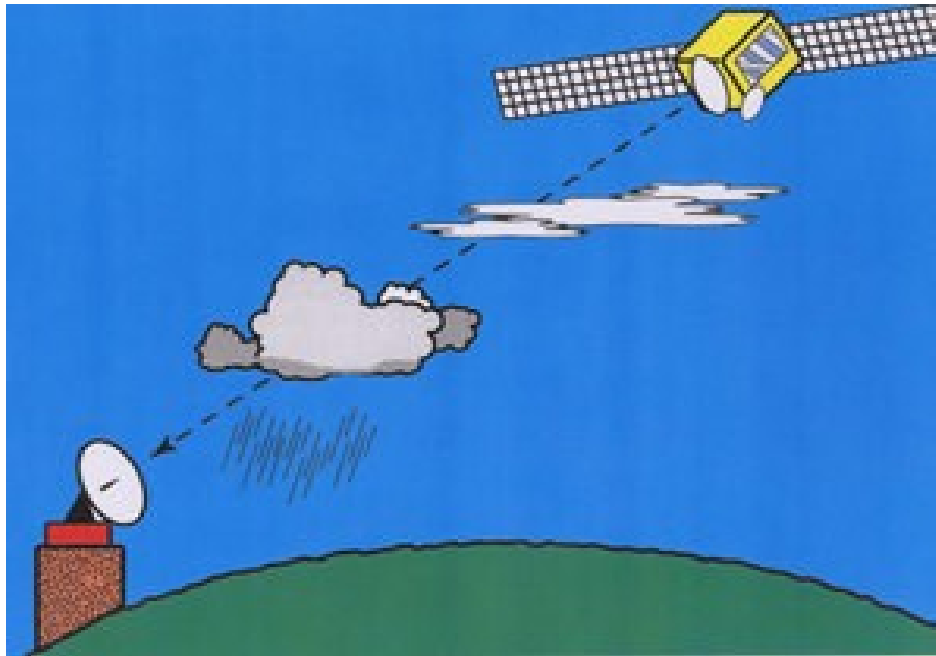
Link allocations in the 38 GHz band in the UK. Total: 13,949 links

Is there a way to pack more links into a given geographical area or a given frequency band?

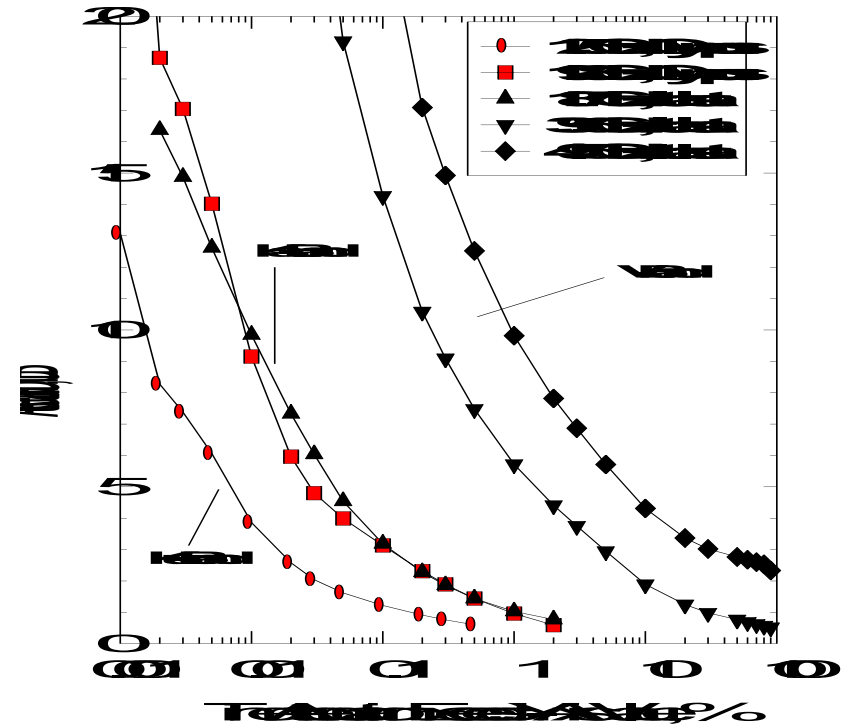
Link distribution in space in the 38 GHz band in the UK.



# Opening higher frequencies to commercial exploitation



Radio systems operating at frequencies above 10 GHz are very affected by the presence of rain, light rain and clouds along the radio path. Fixed radio links can be earth-space or terrestrial.



Attenuation statistics from satellite beacons measured in the South of England

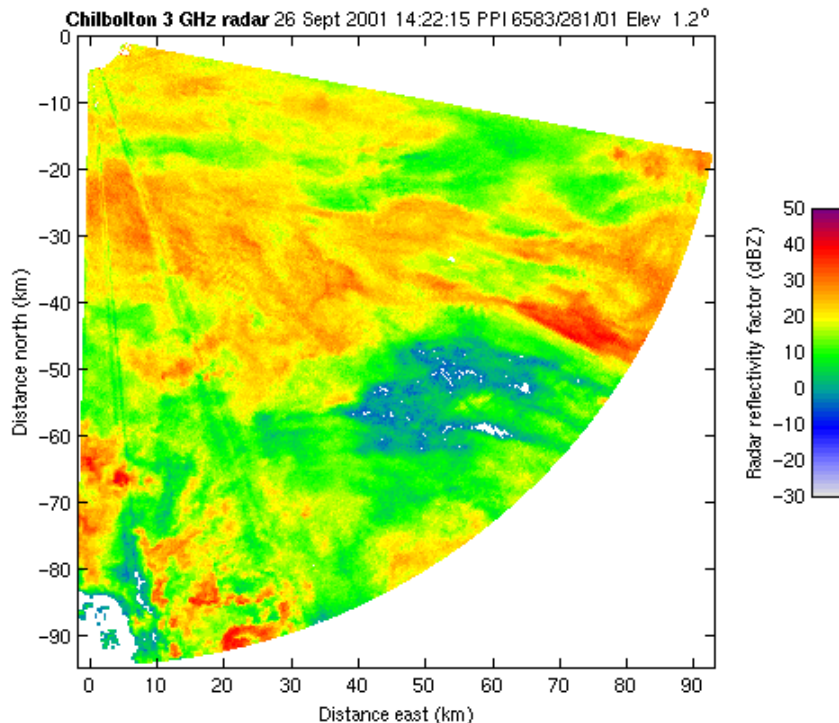


# It doesn't rain everywhere all the time!

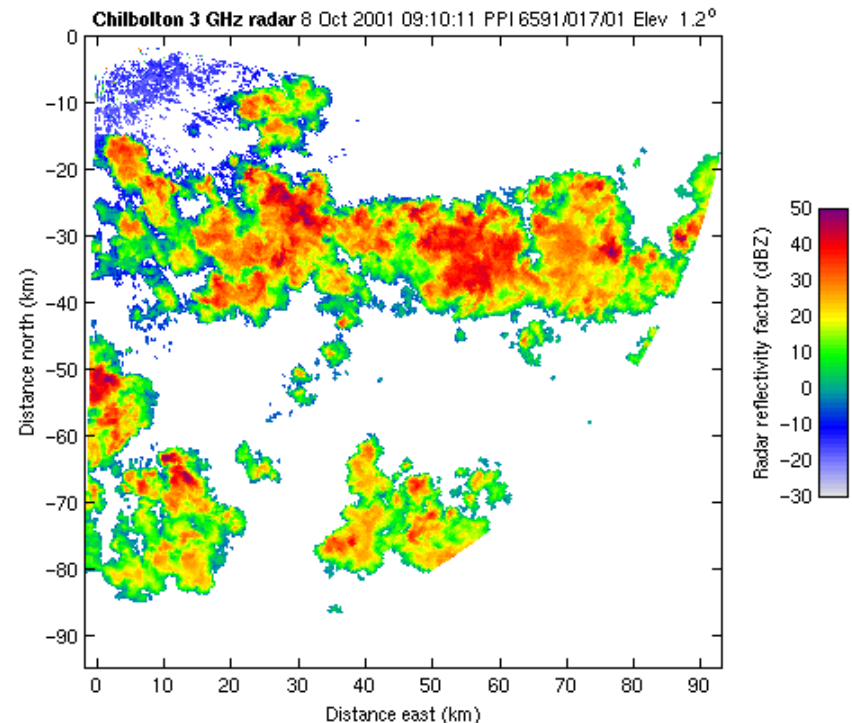
For frequencies  $> 10$  GHz, rain is the dominant cause of attenuation.

We can take advantage of the spatio-temporal variation in rain fields to implement rain Fade Mitigation Techniques (FMTs) to improve spectrum efficiency and open up higher frequencies to commercial exploitation.

Stratiform event



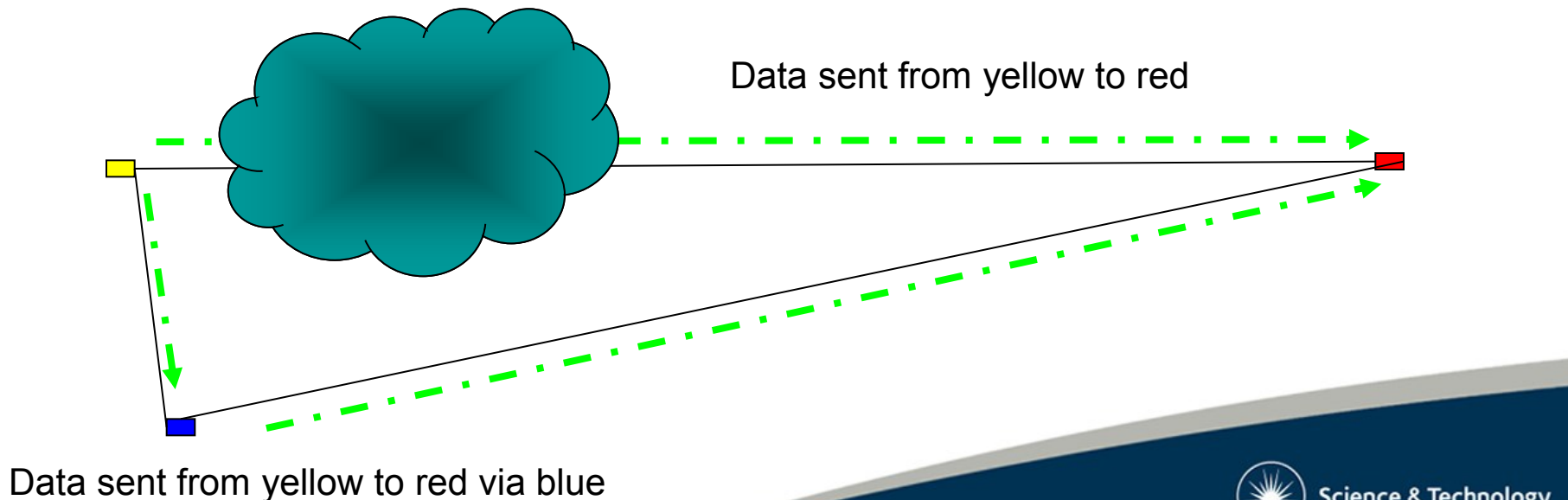
Convective event



# Example radio systems affected by rain: terrestrial network using route diversity

Route diversity involves routing a radio signal through different links which bypass the rain-affected link to get to the same receive point.

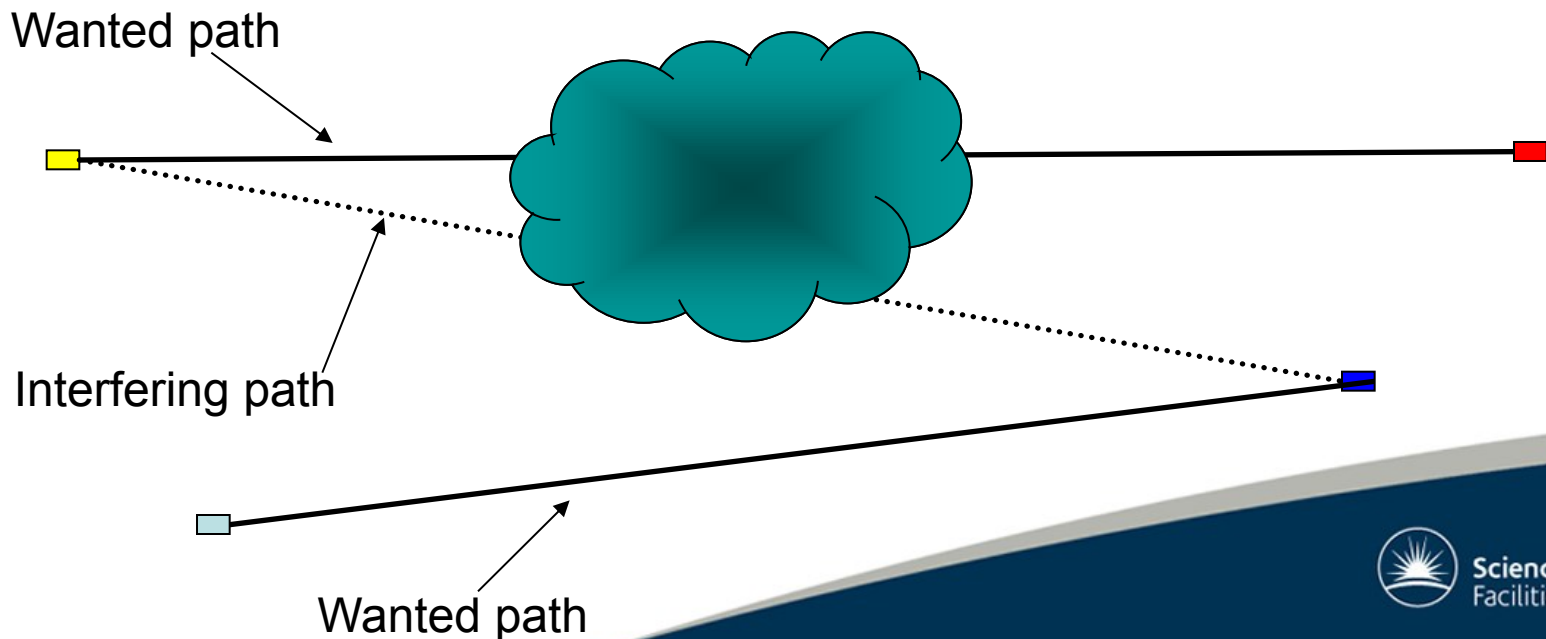
Best case for this is when the rain is de-correlated (localised rain) as neighbouring links in the network will be unaffected and can be used to route the data around the affected link.



# Example radio systems affected by rain: terrestrial network using ATPC

Adaptive Transmit Power Control involves turning the transmit power up to compensate for rain fading. This also increases the transmit power on the sidelobes and unwanted paths, increasing interference into neighbouring links.

Best case is when the rain field is correlated (widespread rain) as the interfering path will then be as attenuated as much as the wanted path, so turning up the power will produce no real change in interference.





# Chilbolton Advanced Meteorological Radar



CAMRa

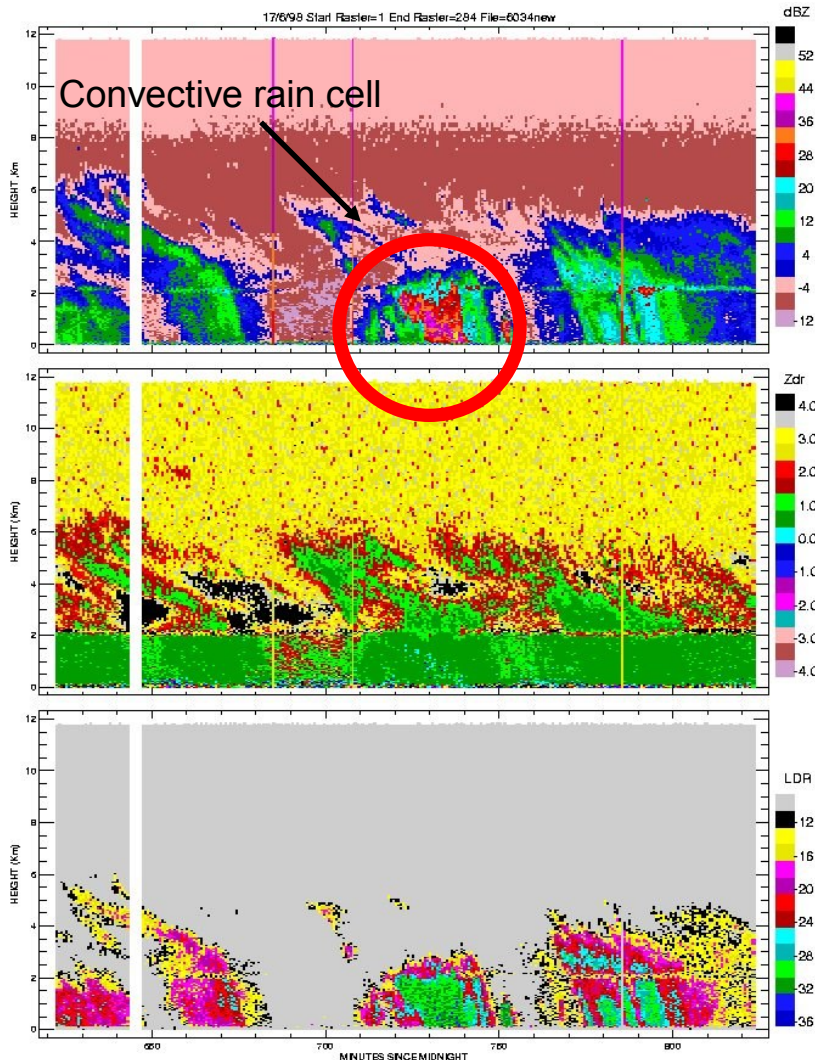
- 25 m diameter steerable antenna
- 60 m tall
- Dish weighs 400 tonnes, tower weighs 2000 tonnes
- 3 GHz Doppler-Polarization radar
- operational range of 100 km
- beam width of 0.25 degrees
- max angular velocity 1 degree / second

Meteorological radar data gives data with very good resolution, which is important when studying the fine detail in rain fields.

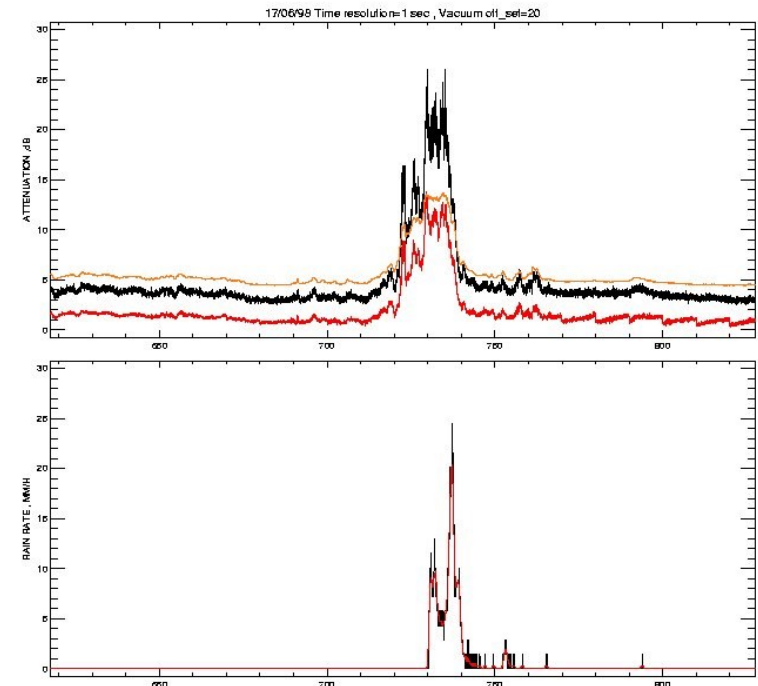


# Convective Rain – Italsat Earth-Space data

Comparison of radar measurements along the path, with concurrent rain gauge and satellite beacon attenuation measurements.

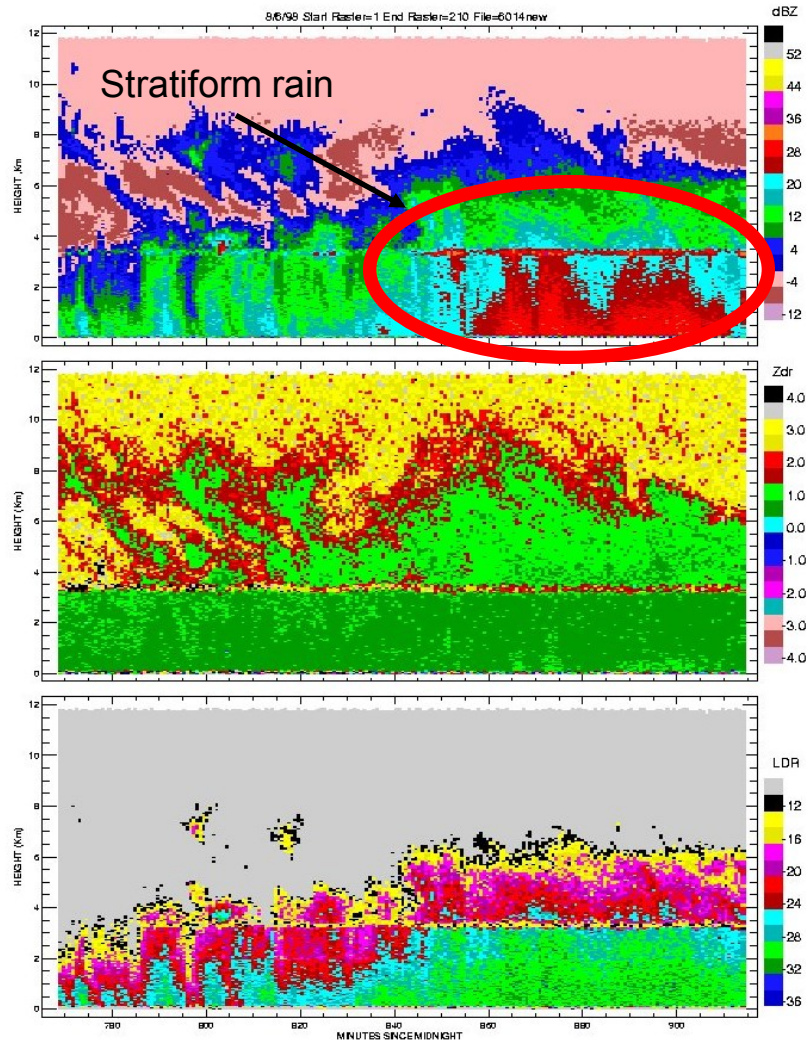


<b>Date of scan:</b>	17/ 6/ 1998
<b>Time covered by scan:</b>	10:20 – 13:40
<b>Maximum radar reflectivities:</b>	48 dBZ
<b>Maximum beacon attenuation:</b>	
<b>50GHz:</b>	25 dB
<b>40GHz:</b>	13 dB
<b>Maximum rain rate recorded:</b>	25mm/ hr
<b>Radiosonde:</b>	
<b>Time:</b>	No data for that date.
<b>Height of 0°C isotherm</b>	

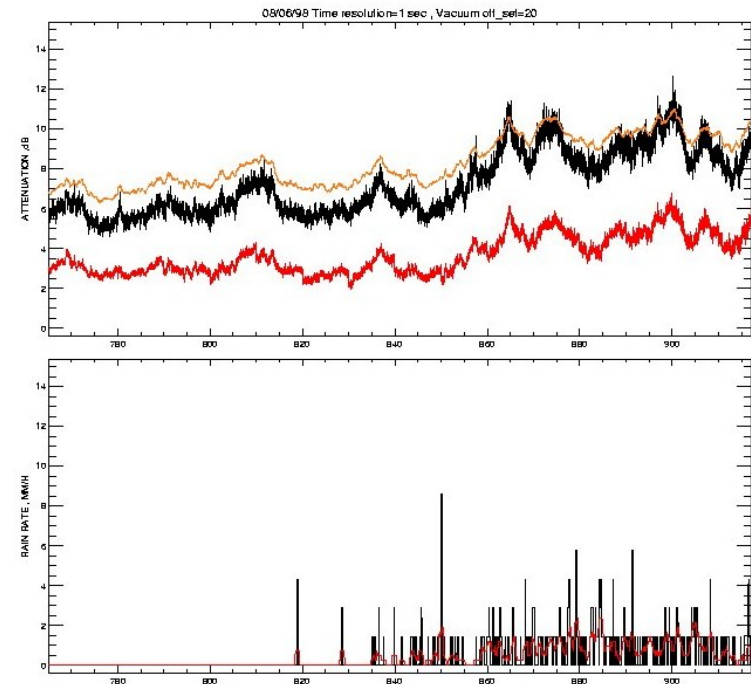


# Stratiform Rain – Italsat Earth-Space Data

Comparison of radar measurements along the path, with concurrent rain gauge and satellite beacon attenuation measurements.



<b>Date of scan:</b>	8/ 6/ 1998
<b>Time covered by scan:</b>	12:50 – 15:10
<b>Maximum radar reflectivities:</b>	30 dBZ
<b>Maximum beacon attenuation:</b>	
<b>50GHz:</b>	13dB
<b>40GHz:</b>	7dB
<b>Maximum rain rate recorded:</b>	9mm/ hr
<b>Radiosonde:</b>	
<b>Time:</b>	10:00
<b>Height of 0°C isotherm</b>	3km



# What rain radar data is available?

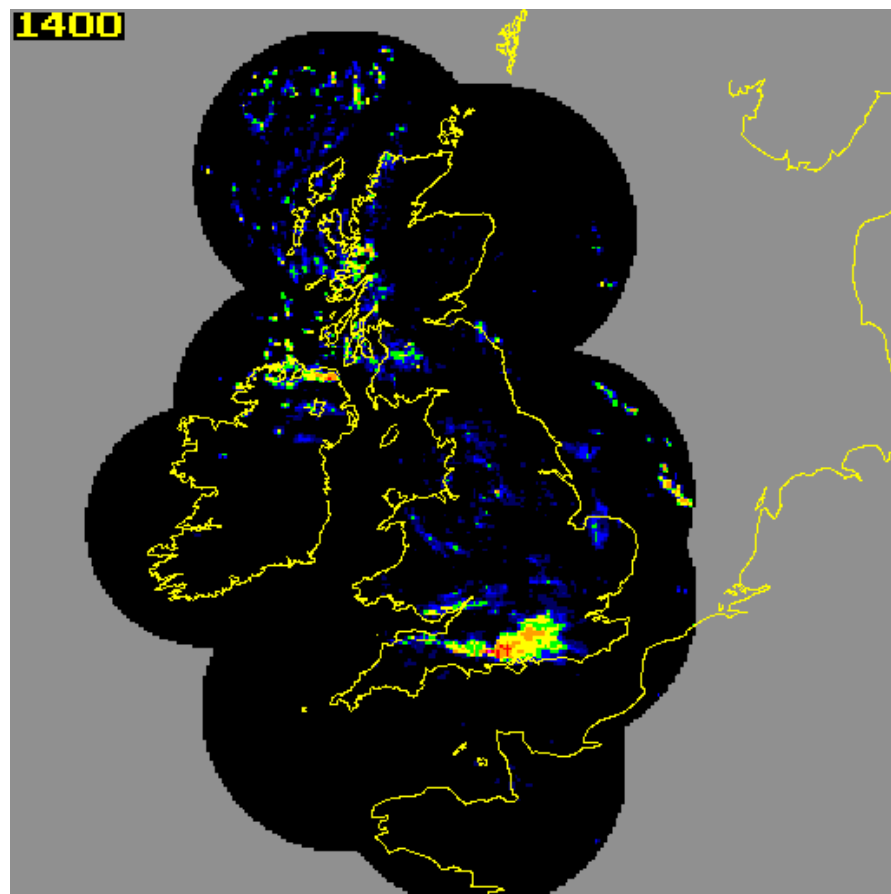
Answer: lots. One dataset is the Met Office's Nimrod data set, which is a database of rain radar measurements available which is composite rain radar data on the Cartesian national grid.

Space resolution: 1/2/5km hybrid  
Time resolution: 5 minutes

Database starts in April 2004.

Before that, composite rain radar data is available on a space resolution of 5 km \* 5 km and at a time resolution of 15 minutes.

Example radar map of the UK derived from the Met Office Nimrod radar data



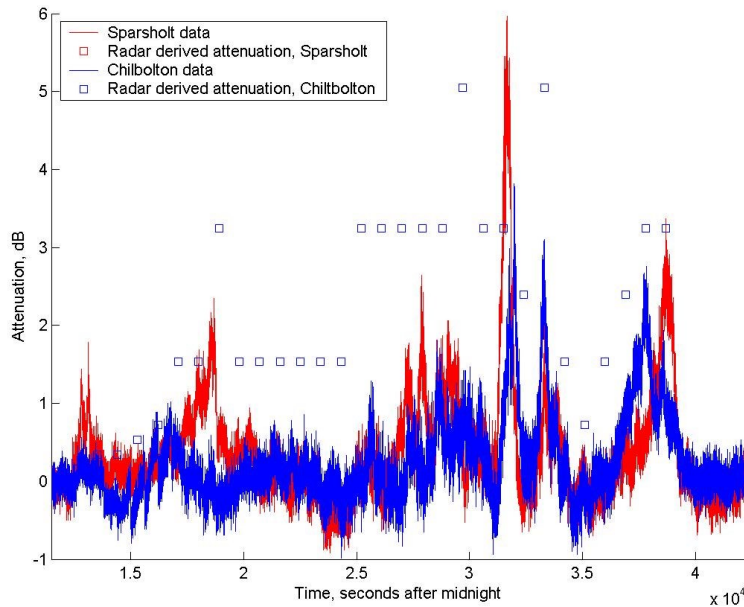


# Can we use the Met Office Nimrod rain radar database to simulate fixed radio link scenarios?

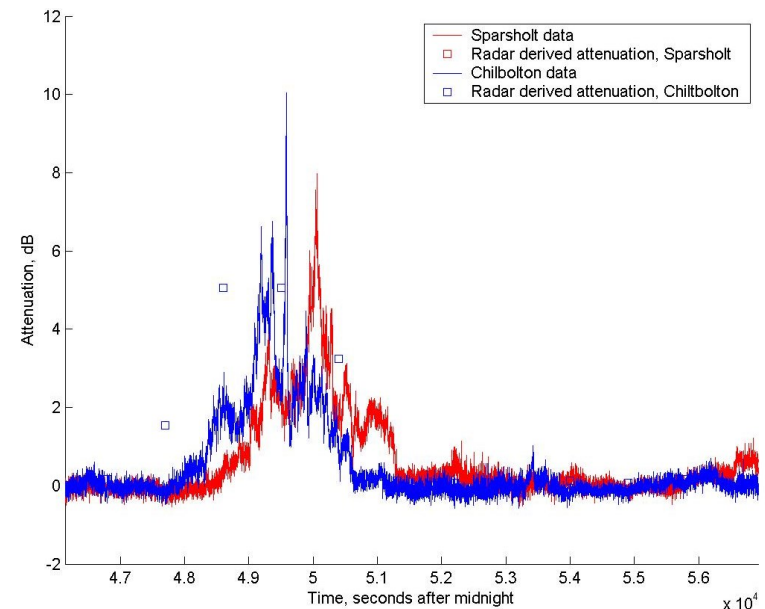
This database is an extremely useful resource for systems designers. However, in this case, the spatial resolution is not high enough to be able to accurately use the data as a substitute for the beacon measurements made in the GBS site diversity experiment.

We either need to make more fine-scale measurements (100mx100m pixel size, at time intervals of less than 1 minute) or look at producing simulated rain fields.

Stratiform event recorded on the 12<sup>th</sup> January 2004.



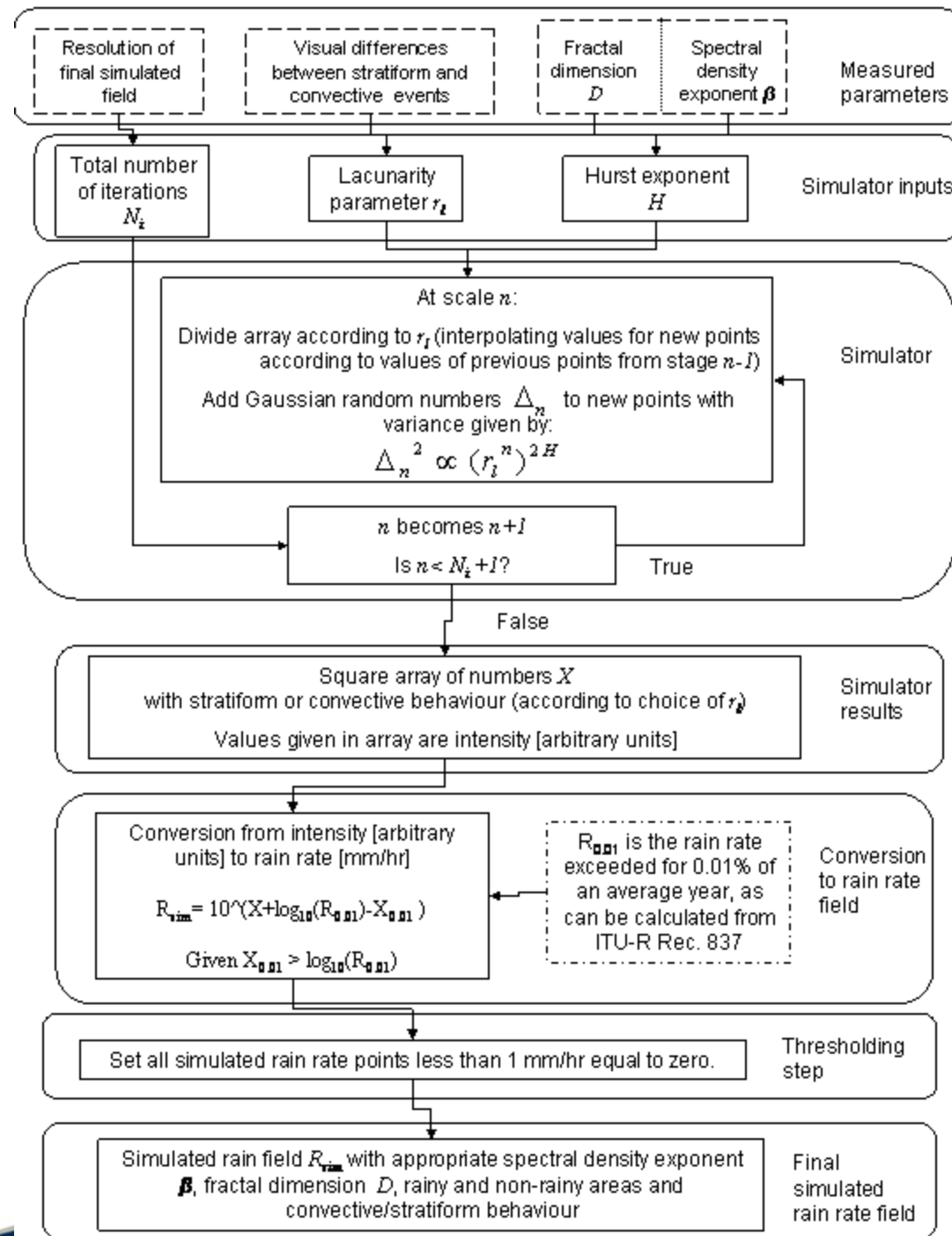
Convective event recorded on the 9<sup>th</sup> January 2004.



# Rain Field Simulator

There are many different techniques used for simulating rain fields. The simulator presented here uses fractal methods, as the fractal nature of rain fields is well documented in the literature.

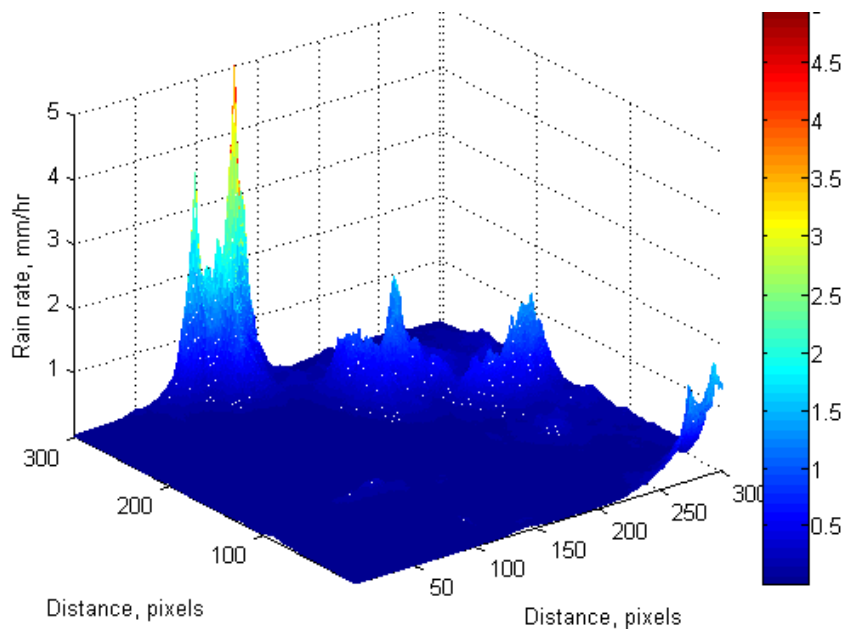
The simulator is based on the Voss successive random additions algorithm for generating fractional Brownian motion in two dimensions. This is an additive discrete cascade, producing log, monofractal fields.



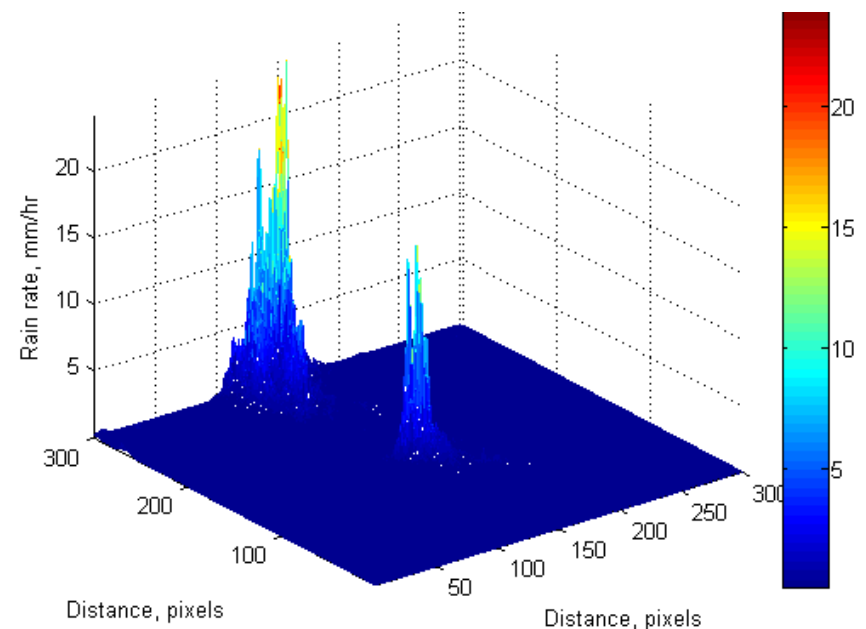
# Example simulated rain fields

Each run of the simulator produces a single realisation of a stratiform-like or a convective-like rain field. These realisations are independent of each other, hence there is no temporal component to the model (work is ongoing). However, given enough synthetic fields we can create simulated statistics for an average year.

Example simulated stratiform rain field.



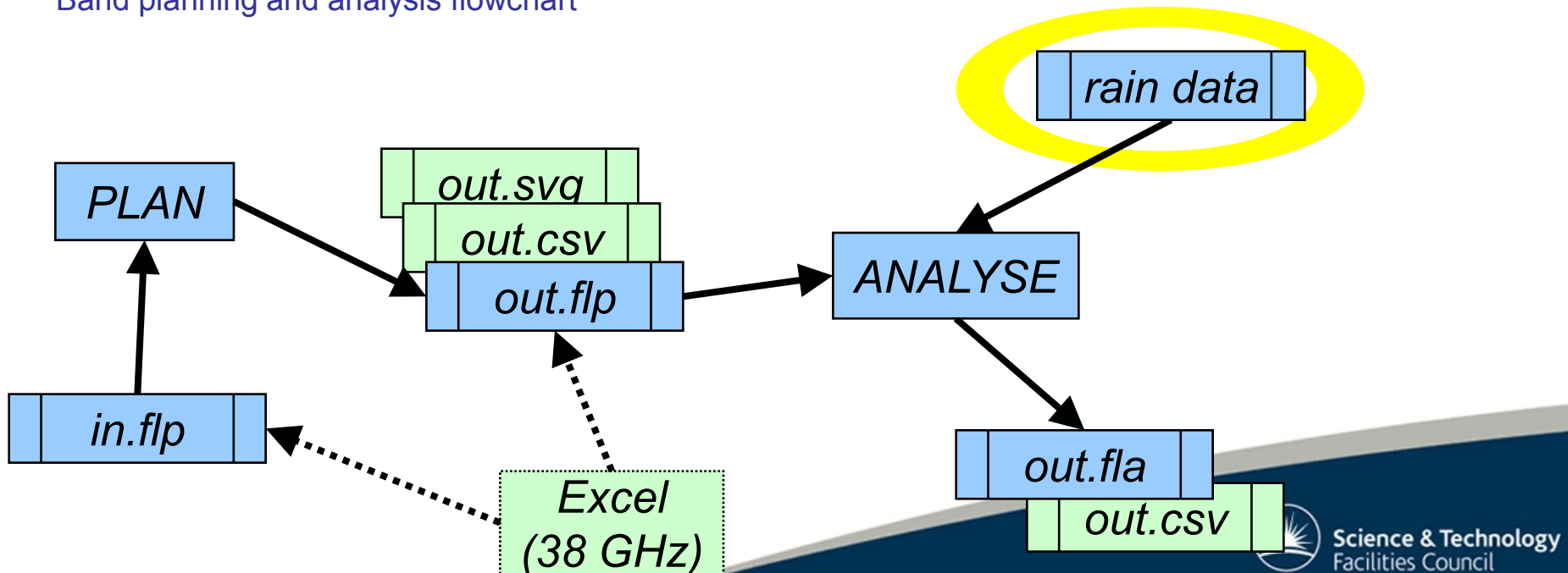
Example simulated convective rain field.



# Applying rain field data to an engineering scenario

Ofcom funded a project to investigate the impact of introducing Automatic Transmit Power Control (ATPC) into the 38 GHz fixed terrestrial links band. This involved using the same methods as Ofcom's existing frequency assignment software, and modifying it to take ATPC into account. It was tested with measured and simulated rain fields.

Band planning and analysis flowchart





# Results from ATPC project and Conclusions

Using ATPC in the 38 GHz band gives significant improvements in spectrum efficiency measured by:

1. the increase in the number of links assigned to channel 1 (from ~50% to ~70%)
2. the decrease in the maximum bandwidth used (from ~300 MHz to ~180 MHz).

The model used here produces rain fields with spatial resolution of 100m\*100m and a time resolution of 1 minute. These fields have the same fractal dimension, spectral density exponent and spatial autocorrelation function as measurements, and can be customised to different climatic regions. They also produce stratiform-like and convective-like behaviour, according to the type of event desired by the operator.

